Phytotoxicology 2001 and 2002 Investigations: Algoma Ore Division, Twp. Of Michipicoten (Wawa)

September 2003

Ontario

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Ministry of the Environment
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Introduction

For several decades, Algoma Steel Corporation operated an iron ore sintering plant near the Wawa townsite in the Township of Michipicoten. Algoma Ore Division (AOD) mined a low grade iron ore, siderite, at nearby deposits and processed this ore at the sinter plant to reduce the sulphur content and make it more suitable for blast furnace feed. Much of the processed ore was shipped to the Algoma steel making operation in Sault Ste. Marie. The primary air emission from the sinter plant was sulphur dioxide, which caused considerable environmental damage in an area to the north-east, known locally as the "fume-kill zone".

AOD ceased operations in 1998. The sinter plant has been razed and the mines closed. However, during its operation the sinter plant also released arsenic, which was present in the iron ore, and a concern about the effects of the soil-deposited arsenic on the health of Wawa residents was raised. In response, in 2000 the Wawa Environmental Steering Committee and the Medical Officer of Health for the Algoma Health Unit commissioned a human health risk assessment and an arsenic exposure survey of the Wawa townsite residents. The later included urine sampling for arsenic determination.

In 2001, in support of the arsenic exposure survey, the MOE Sault Ste. Marie District office requested the assistance of the Phytotoxicology Investigations Unit to sample soil on the residential properties where occupants under the age of 13 had participated in the exposure study. In 2002, additional properties were identified for sampling, either because they were inadvertently excluded the previous year or because other families had joined the exposure study. The properties to be sampled were all identified to the Phytotodxicology investigator as those where urine samples from young residents had been collected. The residential soil arsenic concentrations were provided to the consultant performing the exposure study prior to the preparation of this report.

Additionally, the Phytotoxicology Investigations Unit was asked to evaluate whether the soil concentrations of arsenic encountered on residential properties in Wawa were capable of inhibiting vegetation growth, as arsenic is known to be potentially phytotoxic. In the past, some forms of arsenic were used as herbicide.

Since there were two separate tasks in this investigation, they will be discussed separately in this report.

Investigation Methodology - Residential Property Sampling

Soil samples were collected by Phytotoxicology scientists at 28 residential properties on October 3 and 4, 2001, and at 11 additional properties on July 29, 2002. At most properties two sample sites were established, the sodded portions of the front and rear yards. Occasionally, a side yard was designated as a third sample site. Sampling was conducted using a stainless steel, tube-type soil sampler that extracts a cylindrical core of soil when it is plunged into the ground. Twelve soil cores were collected at each sample site, each to a depth of five centimetres in a grid pattern that covered the entire sample site, and placed into a labelled polyethylene bag. The sampling was repeated to yield duplicate samples from each sample site. The locations of the

properties sampled to support the arsenic exposure survey (i.e. urine analysis) is shown in Figure 1.

Samples were delivered to the Phytotoxicology processing laboratory where they were air dried, sieved through a 2 mm soil sieve to remove stones, roots etc., and then ground in an agate mortar until the soil material passed through a 355 µm soil sieve. Samples were then forwarded to the MOE Laboratory Services Branch for analysis of major and minor soil elements, including arsenic.

Results - Residential Property

All data produced by the analysis of soil samples collected at residential properties are reported in Tables 1, 2 and 3. The data were organized into these three tables based on the locations within the Wawa townsite that samples were collected. Table 1 reports data from properties located along Government Road, near the AOD sinter plant. Table 2 contains data for properties east of Third Avenue and Mission Road. The housing in this area is older and hence it can be assumed that the soil on the property has been less disturbed and exposed to deposition of material from AOD for a longer period of time. Housing west of these streets is newer and hence soil on these properties would have been disturbed by construction and exposed to AOD emissions and arsenic deposition for less time. Data for these properties is reported in Table 3. The soil data in these tables are compared to the Ministry's soil guidelines as outlined in the *Guideline for Use at Contaminated Sites in Ontario* (see Appendix 1). Ministry Table F values are background-based guidelines and Table B are effects-based guidelines. The Ministry's OTR_{98} guidelines (see Appendix 2) are substituted where there are no Table F values. Table B guidelines are not available for all elements, either because there is insufficient toxicological information to establish a guideline, because the element is naturally present in very high concentrations, or because an element is essential for plant growth. Consistent exceedences of Table F guidelines (in bold font in the tables) are an indication the soil has been impacted by a contaminant source.

Discussion - Residential Property

The primary objective of the 2001 and 2002 investigations was to provide soil arsenic concentration data for use by the consultant in the arsenic exposure study. One part of this study was to determine if there was a relationship between the concentrations of arsenic found in the soil of a residential property, and the urine arsenic concentration of residents, particularly young children residing at that property. The soil data for this objective were provided to the consultant prior to the preparation of this report.

The collection of soil samples at various locations throughout the Wawa townsite, as well as from locations close to the AOD operations, provided an opportunity for a more in-depth analysis of how the long-term sinter plant emissions affected the soil chemistry. The comprehensive analysis of the soil samples produced an extensive database of element

concentrations. This made it possible to look for spacial trends across Wawa as well as relationships between elements, and specifically with arsenic.

The residential sampling locations were separated into three categories based on their proximity to AOD and relative length of time that a property has been used for residential purposes. As show in Figure 1, only three properties occurring on Government Road near AOD were identified for sampling as part of the exposure study. Seven sites (yards) were sampled from those three properties. All remaining properties were within the Wawa townsite proper. As a result of the low sample number in this part of the townsite spacial concentration trends should be interpreted with caution.

During the sampling it became apparent that the townsite appeared to have been developed in two stages. Ho uses on the properties east of Third Avenue and Mission Road tended to be older than those to the west of this line. In fact, some to the west were clearly new with some lots still undeveloped.

The rationale for the first category was proximity to AOD; these properties were much closer to the sintering plant than those in the townsite. They were also along a major road that would have been used by vehicles from AOD. These vehicles could have tracked arsenic contaminated material from the plant site. The separation of the second and third category was intuitively based. Properties that contained older housing were more likely to have received air borne deposition of arsenic dust for a longer time period, particularly during the earlier years of AOD's operation s when emission controls were less effective. Construction of recent housing would have disturbed the indigenous soil on these properties and could have involved import of topsoil for landscaping. It would, therefore, be reasonable to expect the highest soil arsenic concentrations to the northwest nearest AOD, the next highest in older residential yards on the east side of the townsite, and lower soil arsenic levels in the newer homes west of Third Ave. and Mission Rd. and east of Tamarack Ave.

To determine if a distribution pattern of arsenic was present, frequency distributions of arsenic concentrations for all samples (replicates considered separately) were generated by calculating the frequency of concentrations in the ranges 0-10 µg/g through 90-100 µg/g and >100 µg/g. The results of this analysis are represented in Figure 2. Each graph in Figure 2 also reports the number of samples (N) that were present in each category of properties.

The frequency distribution of arsenic concentrations for the relatively few samples collected from properties near AOD indicates two distinct groups. An examination of Table 1 shows that six samples from one property account for all data in the 0-10 µg/g range, while the remaining eight samples from two other properties in the same vicinity account for all data in the high concentrations ranges, i.e. greater than 60 µg/g.

A possible explanation is house age. The two properties with the high arsenic concentrations contain houses that appear to be several decades in age. Consequently, their yards have, in all probability not been disturbed since the houses were constructed. The soil in these yards would have received and retained arsenic and other elements that were emitted by AOD. They are also situated next to a road that would have been used by vehicles leaving the AOD site, possibly tracking arsenic contamination from the site itself.

The third property contained a house of recent construction, surrounded by yards that were meticulously landscaped and maintained. It is highly probable that the soil at the surface (which was sampled) is not indigenous to this property, and has not received the deposition of arsenic that other nearby soil has. Also, the residential portion of this property is set in a cleared part of a wooded area, well back from the public road. Evidence that the arsenic data reported for this residential yard is not indicative of the deposition that fell onto the woodlot around the property is provided in the data for the bioassay soil collected from Site 9, which happened to be just a few metres from the rear lawn. The arsenic concentration for this soil was 143 µg/g (Table 5), whereas the soil from the adjacent residential lawn had less than 7 µg/g arsenic (Table 1).

The frequency distributions for all remaining properties, separated into those on the older east part of Wawa and those on the newer west part of the townsite, distinguish themselves from the two properties near AOD (which are probably more typical of others near AOD) because they had arsenic concentrations that are almost all below 40 µg/g. In comparison, all soil samples from the two properties near AOD were above 60 µg/g arsenic.

Having established that residential property soil in the townsite proper has much lower arsenic concentrations on average than at those properties near AOD, it is worthwhile to see if there are any distinctions between east and west Wawa. The similarities between these two groups lies in the near identical frequencies in the 10-20 µg/g and 20-30 µg/g intervals. The differences are in the higher frequency of samples with more than 30 µg/g arsenic from the eastern older side of the townsite and a concomitant higher frequency of samples with less than 10 µg/g from the western side.

If this trend is in fact real, then two explanations can be proposed. First of all, older properties would have been subjected to longer periods of arsenic deposition. Secondly, many of the west side properties are very new housing sites and the possibility of uncontaminated landscaping soil being used to finish the yards appears highly probable. Never-the-less, most of the Wawa townsite properties have reasonably low arsenic concentrations compared to those near AOD. These townsite properties were probably not subjected to fugitive or vehicle-tracked dust from AOD. Also, because of the relatively low height of the AOD stack, the ridge between AOD and the townsite, and the predominantly southwest winds during the non-snow season, much of the stack emissions would have bypassed the townsite depositing instead in the "fume-kill zone" to the northeast. The soil arsenic levels are highest on the residential properties along Government Rd. nearest AOD because these properties are among the oldest in town and are very close to AOD and so they would have been impacted not only by stack deposition but also from fugitive emissions off the AOD plant site and from vehicle traffic.

The final point of discussion regarding the arsenic data has to focus on what appears to be an anomalous property in the east Wawa group. One sample from the back yard was determined to contain 300 µg/g of arsenic (see Table 2). This datum was substantiated by repeat laboratory analysis. The duplicate sample for that yard contained 37 µg/g. It is clear that a very heterogeneous distribution of arsenic is present in the back yard soil at this property. The source of arsenic at this property was not identified but given that at least one other property had fill material imported from the AOD site, it is possible that others may have also. The most

probable use of such material would have been for driveway surfaces, construction aggregate, and fill.

As is evident in the data tables, the soil samples were analysed for much more than just arsenic. Given that these data are available, a brief look at the other soil elements is warranted. A statistical procedure was performed that provided correlation coefficients between each possible pair of elements. The results of this analysis is reported in Table 4 as a correlation matrix.

Due to the high number of samples available for this analysis, the level at which the correlation can be considered statistically significant is very low. In this analysis there were 162 samples and any correlation coefficient (r) with an absolute value of about 0.150 indicates a significant correlation at a confidence level of 99% ($p<0.01$). A positive r value means as one element increases the other element also increases in a consistent proportion. A negative r value indicates one element goes down in concentration as the other increases, or visa versa. The higher the r value the more consistent the relationship between the two and the greater the likelihood of a common origin. Clearly, there are many significant correlations between the concentrations of various pairs of elements in the soil samples collected.

It would be more useful, however, to focus only on those correlations that have the highest r values, and more specifically, those that are co-related to arsenic. To that end, the elements that are most highly correlated with arsenic are iron ($r=0.6355$) and manganese ($r=0.6577$). The correlation between iron and manganese is even greater ($r=0.9270$). This implies that iron and manganese concentrations are likely to be elevated on properties that have high arsenic levels. Since iron is naturally high in soil and both iron and manganese are essential plant nutrients, slightly elevated concentrations of these two elements should not adversely affect plant growth. Given that the purpose of the AOD operation was to process iron ore, and the ore was an arseno-pyrite, the arsenic-iron correlation could be expected. The fact that manganese emissions also occurred can be readily reconciled since the ore processed at AOD contained significant quantities of manganese.

Investigation Methodology - Bioassay

Arsenic can be phytotoxic, and concentrations above the MOE generic effects-based Table A guideline of 20 µg/g may cause injury to sensitive plant species. As this and previous Phytotoxicology investigations around Wawa have documented, soil arsenic concentrations in this community can substantially exceed the MOE generic Table A soil guideline. However, with the exception of the fume-kill zone, vegetation impacts have not been observed in the Wawa area. Although soil arsenic levels can be quite elevated in the fume-kill zone it is not likely that arsenic is a significant contributor to the vegetation damage in that area. The main reason the vegetation has been so dramatically impacted in the fume-kill zone is because of years of intense fumigation by sulphur dioxide, which killed the plants outright. With the plants destroyed and the organic matter in the soil eroded the site is very harsh and exposed and subject to extremes of heat, cold, and moisture stress, making it very difficult for forest-type plants to re-

colonize the fume-kill zone. With the complete cessation of emissions from AOD large areas of the fume-kill zone have re-vegetated with grasses and shrubs, particularly blueberry.

During the residential property sampling, bulk soil was collected at ten locations which were likely to provide a wide range of soil arsenic concentrations. This soil was collected for a bioassay to be conducted at the Phytotoxicology controlled environment laboratory to determine whether the concentrations of arsenic in the soil in Wawa are capable of causing an adverse effect on vegetation.

Once a candidate location was identified, a portable X-ray fluorescence spectrophotometer was used as a field screening measurement to determine the approximate soil arsenic concentration at that location to ensure that soil with a wide arsenic concentration range was being obtained. A garden spade was used to collect approximately ten litres of soil from the uppermost five centimetres at each site. Most of the locations could be described as parks, undeveloped green spaces, or vacant land near the sinter plant property. One location was a pile of soil and rock mixture that was to be used as fill on a residential property and was reported to have originated from the sinter plant property. The locations from which the bioassay soil was obtained are shown in Figure 1. The soil arsenic concentrations in the 10 bioassay samples ranged from 14 µg/g to 533 µg/g (see Table 5).

After air drying, the soil was screened through a two millimetre sieve and the sieved fraction was set aside for the bioassay. Samples for chemical analysis where taken from the now thoroughly homogenized bulk soil for laboratory quality assurance purposes, to confirm the field-screened arsenic levels, and insure there were no potentially phytotoxic levels of other chemical elements. Four replicate samples were taken from the three bulk samples collected in 2001 and three from the seven bulk samples collected in 2002. Processing of these samples destined for chemical analysis followed the same procedures as for the residential samples. In addition to soil with low arsenic concentrations (two sites with 14 µg/g and one site with 15 µg/g) collected from the Wawa area, a greenhouse potting soil was also used as a control. The control potting soil contained less than 17 µg/g arsenic.

Bioassay Methodology

Each of the 10 bioassay soils, now thoroughly homogenized and screened to less than 2 mm, where transferred into three plastic pots. On August 14, 2002, each pot was seeded with five bush bean seeds (a standard bioassay plant known to be very sensitive to arsenic), watered, and placed into a temperature, lighting, and humidity controlled growth chamber. The seeds were allowed to germinate and the plants to develop. The young plants were watered as required. No fertilizer was added. The bioassay ended on September 19, 2004, after 35 days. The pots were removed from the chamber and the plants were photographed. Measurements of above ground plant biomass fresh weight, shoot length, and root elongation were recorded.

Bioassay Results

The chemistry of the bioassay soil samples is reported in Table 5. Values are reported as means of the four replicate samples. Arsenic was the only element that exceeded MOE Table A generic effects-based soil guidelines. Some bioassay treatment soils had levels of iron, magnesium, manganese, and/or zinc that were marginally higher than normal background concentrations, but all were well below the Ministry's Table A generic effects-based soil guidelines. These marginally elevated concentrations of iron, manganese, magnesium, and zinc would not have adversely affected plant growth, in fact they may have been benificial as they are all nutrient elements that are essential for plant growth.

Photographs were taken at the end of the bioassay and are represented in Figure 3. These images have been cropped and scaled so that each image is at the same scale and a visual comparison of the response of the bean grown in the ten different soils can be readily made.

Table 6 summarizes the bean growth measurements for each soil arsenic treatment. The mean above ground plant biomass fresh weight was greatest for bean plants grown in 110 µg/g arsenic, whereas the mean shoot length was longest at 14 µg/g soil arsenic, and on average the plants with the longest roots grew in 350 µg/g soil arsenic. On average, plant above ground biomass, shoot length, and root length were all marginally greater at the highest soil arsenic concentration of 533 µg/g than the greenhouse control soil which contained less than 17 µg/g.

Discussion - Bioassay

The images in Figure 3 clearly illustrate the relatively uniform growth obtained in all bioassay soil treatments. The similar between-treatment growth illustrated in Figure 3 is supported by the plant measurements summarized in Table 6, which indicated that there was no consistent relationship between plant growth and soil arsenic concentration, and that plant growth was similar across the range of soil arsenic treatments.

Most seeds germinated and bean plants developed with no signs of toxicity. Arsenic toxicity typically induces black, necrotic leaf tissue and blackened, knotted, and shortened roots. There was no difference in bean germination or apparent difference in plant growth between soil arsenic levels. In some pots a fungal infection slightly inhibited growth on a few plants. Slight differences in total plant height were not related to soil arsenic concentration and were likely the result of varying fertility levels in the test soil (no fertilizer was added).

No injury symptoms characteristic of arsenic toxicity were observed on any of the bioassay plants at any soil arsenic concentration. The highest soil arsenic concentration tested was 533 µg/g, or about 26 times the MOE Table A generic effects-based arsenic soil guideline. The absence of arsenic toxicity symptoms in the soil bioassay is consistent with the complete lack of arsenic symptomatology on vegetation in Wawa - no injury symptoms characteristic of arsenic toxicity on vegetation have been observed by Phytotoxicology investigators since intensive Ministry studies were initiated in 1998.

In order for injury to occur the arsenic must be biologically available to the plant, which means it must be soluble in water and taken up through the roots. The arsenic in soil in Wawa must be very insoluble in water because no injury was observed in the bioassay plants, or plants anywhere in the Wawa townsite, and no adverse impacts were measured in bioassay plants at the maximum soil arsenic concentration tested (533 µg/g). Therefore, the risk to the terrestrial ecosystem in Wawa from elevated soil arsenic concentrations is concluded to be very low. The bioassay results are completely consistent with observations of vegetation health in the general Wawa area and support the conclusions that elevated soil arsenic concentrations, up to the maximum tested concentration of 533 µg/g, will not adversely affect plant growth and therefore there are no restrictions to the normal use of residential properties in Wawa.

Conclusions

The primary objective of this investigation was to provide data on arsenic concentrations in soil of specific residential properties to support health studies. This objective was met by providing these data to the appropriate parties before this summary report was prepared.

The sampling of numerous properties at the Wawa townsite as well as in the vicinity of AOD provided a sizeable database of soil element concentrations that permitted a general evaluation of soil contamination. This evaluation demonstrated that arsenic concentrations in residential property soil for the Wawa townsite were generally less than 50 µg/g, with a few exceptions on properties closest to AOD or where contaminated soil or aggregate material was brought to the property.

Properties near the AOD site consistently had higher arsenic levels. These properties would have been subject to more intense deposition of AOD atmospheric and fugitive emissions, as well as tracking of the contaminant by vehicles from AOD.

The bioassay revealed that symptoms of arsenic toxicity could not be induced in a sensitive plant species at soil arsenic concentrations up to 533 µg/g, which is considerably higher than all but a few of the most contaminated residential Wawa residential properties nearest AOD. In conclusion, the form of arsenic in the soil in Wawa must be very insoluble and therefore biologically unavailable, and so the risk to the terrestrial ecosystem in the Wawa area from elevated soil arsenic concentrations is concluded to be very low. The bioassay results are completely consistent with observations of vegetation health in the general Wawa area and support the conclusions that elevated soil arsenic concentrations, up to the maximum tested concentration of 533 µg/g, will not adversely affect plant growth and therefore there are no restrictions to the normal use of residential properties in Wawa.

Table 1: Soil Element Concentrations (µg/g) on Residential Yards of Properties Near Algoma Ore Division

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
A Government Rd.	front	3300	14000	12000	2900	320	59	46	25	16	31	33	35	31	5.5	3.9	0.5 <W	0.5 <W	0.2 <W
A Government Rd.	front	3800	14000	10000	3100	360	47	39	26	18	29	22	27	24	6.2	4.5	0.5 <W	0.5 <W	0.3 <T
A Government Rd.	side	3200	10000	5400	2600	240	15	16 <T	19	13	19	9.0 <T	7.0	11	4.4	4.0	0.5 <W	0.5 <W	0.2 <W
A Government Rd.	side	3600	12000	6300	2900	320	18	21 <T	21	15	22	10	9.0	13	4.8	5.1	0.5 <W	0.5 <W	0.2 <W
A Government Rd.	back	3800	11000	5900	3100	270	16	17 <T	18	13	21	13	7.0	12	4.6	3.9	0.5 <W	0.5 <W	0.2 <W
A Government Rd.	back	5000	11000	5400	3400	280	15	17 <T	18	13	21	9.0 <T	8	11	4.3	6.4	0.5 <W	0.5 <W	0.3 <T
B Government Rd.	front	4700	**42000**	12000	4900	**1900**	63	99	35	22	36	43	43	33	7.6	**98**	0.5 <W	0.5 <W	1.1
B Government Rd.	front	4800	33000	18000	4500	1200	88	93	38	25	44	24	63	**47**	8.0	**69**	0.7 <T	0.5 <W	0.4 <T
B Government Rd.	back	5300	**47000**	8900	5200	**2100**	55	120	31	21	28	49	27	20	6.2	**100**	0.5 <W	0.6 <T	0.7 <T
B Government Rd.	back	5500	**51000**	9500	6300	**2300**	46	130	31	18	32	35	37	25	8.7	**110**	0.5 <W	0.5 <W	1.1
C Government Lane	front	4800	**44000**	8800	5700	**1900**	32	130	29	20	33	57	27	25	8.3	**89**	0.5 <W	0.5 <W	0.9 <T
C Government Lane	front	5100	**44000**	9300	5700	**2000**	35	130	29	21	35	63	28	24	8.3	**96**	0.5 <W	0.5 <W	1.1
C Government Lane	back	3800	25000	7100	3600	1100	31	63	21	13	22	24	16	21	5.5	**72**	0.5 <W	0.5 <W	0.3 <T
C Government Lane	back	4200	26000	6700	3800	1100	28	120	21	15	24	23	13	16	5.4	**84**	0.5 <W	0.5 <W	0.2 <W
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 2: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Townsite Properties East of Third Ave. & Mission Rd.

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
D Wood Ave.	front	3700	20000	12000	4100	580	42	65	37	21	35	23	24	21	7.7	**22**	0.5 <W	0.5 <W	0.4 <T
D Wood Ave.	front	3400	19000	11000	3800	540	40	52	35	19	34	22	22	20	7.1	16	0.5 <W	0.5 <W	0.5 <T
D Wood Ave.	back	2800	19000	14000	3500	510	34	62	36	18	31	17	20	21	7.2	15	0.5 <W	0.5 <W	0.4 <T
D Wood Ave.	back	2500	16000	12000	3200	380	26	47	31	17	28	11	13	17	5.9	9.6	0.5 <W	0.5 <W	0.5 <T
E Second Ave.	front	4300	18000	12000	3200	540	69	68	32	22	29	41	25	18	5.9	**23**	0.5 <W	0.7 <T	0.4 <T
E Second Ave.	front	5200	19000	11000	3300	580	83	67	33	26	28	37	29	18	6.3	**18**	0.5 <W	1.1 <T	0.9 <T
E Second Ave.	back	5300	26000	14000	5200	820	67	110	43	23	44	27	26	29	11	**25**	0.5 <W	0.6 <T	**1.1**
E Second Ave.	back	4000	22000	12000	4100	740	52	93	34	20	35	32	20	23	7.4	**25**	0.5 <W	0.5 <W	1.0
F Second Ave.	front	5900	24000	11000	4000	720	46	120	33	26	33	42	31	27	7.5	**21**	0.5 <W	0.5 <W	1.0
F Second Ave.	front	4900	23000	11000	3700	670	44	100	34	21	33	42	25	18	6.8	**21**	0.5 <W	0.6 <T	0.7 <T
F Second Ave.	back	4700	30000	12000	5000	980	50	**170**	39	22	35	120	34	25	9.2	**35**	0.5 <W	0.5 <W	**1.2**
F Second Ave.	back	5200	30000	11000	4700	970	54	**190**	37	22	38	**140**	37	25	8.8	**38**	0.5 <W	0.5 <W	**1.4**
G Main St.	front	4800	17000	8200	3300	590	73	81	28	23	23	40	23	18	5.7	**18**	0.5 <W	0.5 <W	0.7 <T
G Main St.	front	4800	17000	8500	3500	520	82	77	30	26	26	42	24	19	5.8	**18**	0.5 <W	0.5 <W	0.5 <T
G Main St.	back	3100	14000	8500	2700	370	39	72	27	19	23	34	12	14	4.9	14	0.5 <W	0.5 <W	0.6 <T
G Main St.	back	3000	13000	8200	2600	340	37	70	26	19	21	25	12	13	4.9	10	0.5 <W	0.5 <W	0.5 <T
H Joliet St.	front	5800	16000	9800	3900	420	35	46	31	24	31	24	24	19	7.4	7.5	0.5 <W	0.5 <W	0.5 <T
H Joliet St.	front	5200	15000	9200	3700	360	31	39	32	22	29	18	22	18	6.5	11	0.5 <W	0.5 <W	0.3 <T
H Joliet St.	back	3500	14000	9500	3400	380	40	63	28	19	31	19	19	19	6.7	15	0.5 <W	0.5 <W	0.4 <T
H Joliet St.	back	3200	14000	9000	3400	380	35	56	28	19	34	19	17	17	6.3	15	0.5 <W	0.5 <W	0.7 <T
I Centennial Ave.	front	5700	25000	16000	5000	800	49	66	53	22	44	22	33	25	11	**19**	0.5 <W	0.8 <T	0.6 <T
I Centennial Ave.	front	5800	26000	17000	5600	840	49	73	53	22	48	26	39	27	12	15	0.5 <W	1.5 <T	0.7 <T
I Centennial Ave.	back	3700	15000	10000	2500	420	38	57	30	16	23	24	15	12	4.9	15	0.5 <W	0.5 <W	0.8 <T
I Centennial Ave.	back	3900	16000	10000	2400	450	42	63	32	18	21	19	13	13	4.6	**18**	0.5 <W	0.5 <W	0.5 <T
J Broadway Ave.	front	4300	16000	11000	3200	480	54	52	30	23	29	27	38	17	5.7	17	0.5 <W	0.5 <W	0.7 <T
J Broadway Ave.	front	4300	16000	10000	3100	480	51	60	29	19	33	25	20	16	5.8	15	0.5 <W	0.5 <W	0.2 <W
J Broadway Ave.	back	3100	15000	11000	2700	460	46	79	27	16	27	22	20	19	5.6	16	0.5 <W	0.5 <W	0.6 <T
J Broadway Ave.	back	3100	14000	11000	2800	400	45	74	26	18	25	22	16	17	5.5	17	0.5 <W	0.5 <W	0.3 <T
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 2: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Townsite Properties East of Third Ave. & Mission Rd.

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
K Toronto Ave.	front	8100	22000	12000	4100	790	80	**200**	33	28	37	82	28	21	7.3	**20**	0.5 <W	0.5 <W	**1.1**
K Toronto Ave.	front	7200	22000	13000	4200	790	79	160	37	27	44	63	29	23	8.2	**19**	0.5 <W	0.5 <W	0.8 <T
K Toronto Ave.	back	3900	15000	12000	3500	450	43	93	31	19	31	28	24	19	6.3	17	0.5 <W	0.5 <W	0.4 <T
K Toronto Ave.	back	3800	16000	12000	3600	480	44	98	34	20	31	29	23	19	7.3	16	0.5 <W	0.5 <W	0.6 <T
L Toronto Ave.	front	3400	12000	7800	3000	270	28	46	25	20	24	20	13	14	4.9	9.6	0.5 <W	0.5 <W	0.4 <T
L Toronto Ave.	front	3400	15000	8400	3100	380	34	71	29	21	26	26	16	15	5.4	8.6	0.5 <W	0.5 <W	0.2 <W
L Toronto Ave.	back	3500	12000	7900	2700	250	33	66	23	19	22	21	10	13	4.9	5.8	0.5 <W	0.5 <W	0.3 <T
L Toronto Ave.	back	3600	12000	7500	2600	290	39	82	21	18	21	38	11	13	4.9	9.8	0.5 <W	0.5 <W	0.5 <T
M Toronto Ave.	front	3600	17000	11000	3200	450	40	73	33	18	33	41	23	17	6.3	**20**	0.5 <W	0.5 <W	0.5 <T
M Toronto Ave.	front	3600	17000	10000	3700	440	37	68	32	19	33	42	27	19	7.9	14	0.5 <W	0.5 <W	0.7 <T
M Toronto Ave.	back	3600	16000	9800	3200	470	39	76	29	19	27	30	14	16	5.4	**19**	0.5 <W	0.5 <W	0.6 <T
M Toronto Ave.	back	3200	15000	9000	3000	420	35	66	28	18	25	22	13	15	5.6	17	0.5 <W	0.5 <W	0.4 <T
N Toronto Ave.	front	5500	21000	15000	4700	860	58	130	37	22	43	16	35	34	10	**20**	0.5 <W	0.5 <W	0.3 <T
N Toronto Ave.	front	5100	20000	14000	4200	890	54	120	34	22	42	15	32	30	8.8	**21**	0.5 <W	0.5 <W	0.4 <T
N Toronto Ave.	back	3600	18000	9900	3800	530	34	70	33	21	30	21	17	18	6.5	**20**	0.5 <W	0.5 <W	0.3 <T
N Toronto Ave.	back	4100	16000	9700	3600	630	46	88	32	21	31	15	14	17	6.6	16	0.5 <W	0.5 <W	0.6 <T
O First Ave.	front	5000	25000	14000	4000	870	68	150	41	27	42	40	45	26	9.3	**41**	0.5 <W	0.5 <W	0.8 <T
O First Ave.	front	7100	23000	11000	4900	860	49	110	38	25	39	43	27	21	7.9	**41**	0.5 <W	0.5 <W	0.6 <T
O First Ave.	back	7100	33000	13000	5900	1300	53	130	43	28	48	48	35	28	9.8	**300**	0.5 <W	0.5 <W	0.4 <T
O First Ave.	back	4600	22000	12000	3400	730	60	160	35	24	36	**190**	41	21	7.9	**37**	0.5 <W	0.5 <W	1.2
P First Ave.	front	4600	22000	13000	4400	750	42	82	36	22	45	38	31	22	9.2	**22**	0.5 <W	1.4 <T	1.0
P First Ave.	front	4600	22000	13000	4400	770	41	82	37	21	43	41	32	22	9.0	**18**	0.5 <W	1.3 <T	0.6 <T
P First Ave.	back	3700	20000	11000	3200	620	38	46	34	17	28	23	15	15	5.3	**22**	0.5 <W	0.9 <T	0.3 <T
P First Ave.	back	4100	18000	11000	2800	620	40	48	32	17	25	44	15	14	5.1	**24**	0.5 <W	0.6 <T	1.0
Q Nyman Ave.	front	3100	11000	7500	2300	290	23	37	22	15	26	14	10	12	4.6	9.4	0.5 <W	0.5 <W	0.8 <T
Q Nyman Ave.	front	2800	10000	7400	2200	270	22	31	21	15	25	12	8.0	11	4.1	8.2	0.5 <W	0.5 <W	0.6 <T
Q Nyman Ave.	back	2500	12000	7200	2600	330	26	33	23	12	21	8.0 <T	12	13	5.7	12	0.5 <W	0.5 <W	0.2 <W
Q Nyman Ave.	back	2900	12000	7300	2700	320	27	33	23	14	20	9.0 <T	11	12	5.0	11	0.5 <W	0.6 <T	0.3 <T
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 3: Soil Element Concentrations (ug/g) on Residential Yards, Wawa Townsite Properties West of Third Ave. & Mission Rd.

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
R Beck Ave.	front	3900	19000	10000	4900	510	29	54	35	23	35	25	20	24	8.0	7.4	0.5 <W	0.5 <W	0.2 <W
R Beck Ave.	front	4300	20000	10000	5200	580	33	64	36	24	37	20	24	25	8.8	12	0.5 <W	0.5 <W	0.5 <T
R Beck Ave.	back	3200	21000	11000	3000	640	42	82	32	20	25	28	11	16	5.2	**23**	0.5 <W	0.8 <T	0.6 <T
R Beck Ave.	back	2900	21000	12000	2800	610	38	60	34	19	24	23	11	15	4.9	**24**	0.5 <W	0.5 <W	0.6 <T
S Maple St.	front	4200	16000	11000	3400	400	33	34	32	21	27	15	22	29	6.4	17	0.5 <W	0.6 <T	0.5 <T
S Maple St.	front	3200	15000	10000	2800	360	28	28	28	18	26	8.0 <T	17	23	5.4	17	0.5 <W	0.5 <W	0.2 <W
S Maple St.	side	4000	16000	11000	3400	400	36	37	31	20	28	11	23	30	6.7	15	0.5 <W	0.5 <W	0.6 <T
S Maple St.	side	3700	15000	9800	3100	360	31	30	27	19	25	12	19	25	5.7	15	0.5 <W	0.5 <W	0.4 <T
S Maple St.	back	4200	16000	8400	3300	510	26	26	25	19	23	6.0 <T	15	22	5.9	9.0	0.5 <W	0.5 <W	0.3 <T
S Maple St.	back	4000	14000	8200	3100	450	25	21 <T	24	19	23	10	13	20	5.3	6.8	0.5 <W	0.5 <W	0.3 <T
T Maple St.	front	5100	23000	26000	4400	510	150	100	45	27	66	7.0 <T	85	**69**	10	3.8	0.9 <T	0.9 <T	0.6 <T
T Maple St.	front	5700	24000	**29000**	4500	570	170	110	48	30	60	5.0 <T	94	**74**	11	5.5	1.1 <T	0.5 <W	0.8 <T
T Maple St.	side	5200	23000	26000	4000	630	160	100	44	27	55	8.0 <T	83	**67**	12	6.4	1.0 <T	0.5 <W	0.8 <T
T Maple St.	side	5400	23000	**30000**	4200	540	180	110	48	30	62	7.0 <T	94	**76**	11	4.8	1.1 <T	0.5 <W	0.8 <T
T Maple St.	back	5000	19000	20000	4100	570	110	77	39	25	50	6.0 <T	63	**52**	10	7.6	0.7 <T	0.5 <W	0.5 <T
T Maple St.	back	4900	22000	26000	4200	550	150	100	46	28	56	6.0 <T	**88**	**68**	11	4.0	1.0 <T	0.7 <T	0.7 <T
U Birch St.	front	4600	18000	8300	4100	570	22	32	28	16	26	5.0 <T	18	22	6.3	9.9	0.5 <W	0.5 <W	0.4 <T
U Birch St.	front	3700	18000	8200	3500	560	22	37	26	16	28	9.0 <T	18	22	6.4	14	0.5 <W	0.5 <W	0.7 <T
U Birch St.	back	3000	16000	9900	3200	380	21	27	30	15	28	6.0 <T	14	24	5.9	15	0.5 <W	1.0 <T	0.4 <T
U Birch St.	back	3400	16000	9400	3300	530	33	44	29	18	25	9.0 <T	16	17	7.1	12	0.5 <W	0.5 <W	0.6 <T
V Superior Ave.	front	6800	23000	11000	5000	880	50	58	25	26	32	15	43	20	7.0	**19**	0.5 <W	0.7 <T	0.8 <T
V Superior Ave.	front	7400	26000	12000	6200	910	53	58	32	25	45	15 <T	49	29	8.5	**20**	0.5 <W	0.5 <W	0.6 <T
V Superior Ave.	back	7600	23000	15000	5800	870	66	46	30	26	40	14	76	23	7.8	**23**	0.5 <W	0.6 <T	0.8 <T
V Superior Ave.	back	7800	24000	14000	5700	970	67	51	28	26	40	13	56	24	7.0	**22**	0.5 <W	0.5 <W	0.6 <T
W Superior Ave.	front	3600	18000	9300	4100	500	29	33	32	21	29	12	16	18	7.8	15	0.5 <W	0.5 <W	0.3 <T
W Superior Ave.	front	3900	20000	9500	4300	530	25	34	34	18	33	17	17	19	7.2	16	0.5 <W	0.5 <W	0.3 <T
W Superior Ave.	back	4400	20000	9800	3300	670	54	75	37	20	30	19	15	15	6.0	**20**	0.5 <W	0.5 <W	0.4 <T
W Superior Ave.	back	3600	21000	10000	3400	630	46	67	37	17	30	20	12	14	5.7	**20**	0.5 <W	0.5 <W	0.7 <T
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 3: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Townsite Properties West of Third Ave. & Mission Rd.

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
X Superior Ave.	front	4700	24000	16000	5000	690	38	55	42	19	44	14	49	25	11	15	0.5 <W	**2.6**	0.6 <T
X Superior Ave.	front	3700	20000	13000	4200	500	31	46	36	16	38	11	36	23	9.1	**18**	0.5 <W	1.6 <T	0.4 <T
X Superior Ave.	back	2900	21000	14000	3900	540	36	41	36	15	33	13	24	20	7.8	17	0.5 <W	0.9 <T	0.7 <T
X Superior Ave.	back	3400	22000	13000	4600	590	39	48	36	17	38	18	29	23	8.3	**18**	0.5 <W	1.2 <T	0.5 <T
Y Regina Cres.	front	3200	13000	8400	2600	490	28	30	24	15	20	11	8.0	12	5.1	14	0.5 <W	0.5 <W	0.6 <T
Y Regina Cres.	front	2900	13000	7800	2500	490	29	32	22	14	20	10	8.0	12	4.1	13	0.5 <W	0.5 <W	0.6 <T
Y Regina Cres.	back	2300	14000	7300	1700	570	41	36	21	13	19	21	8.0	7.6	3.2	**28**	0.5 <W	0.5 <W	0.6 <T
Y Regina Cres.	back	3200	20000	8800	2700	930	54	49	26	16	21	33	10	12	3.7	**39**	0.5 <W	0.5 <W	0.7 <T
Z Regina Cres.	front	5000	20000	14000	5000	510	41	53	37	22	38	15	43	25	11	9.9	0.5 <W	1.2 <T	0.5 <T
Z Regina Cres.	front	5000	20000	14000	4900	500	40	53	36	22	38	19	44	24	10	11	0.5 <W	1.4 <T	0.5 <T
Z Regina Cres.	back	5200	23000	12000	4600	780	53	71	38	25	30	14	17	20	7.6	17	0.5 <W	0.5 <W	0.7 <T
Z Regina Cres.	back	14000	22000	12000	4500	**1700**	210	110	34	**120**	30	23	24	20	8.3	**20**	0.5 <W	0.5 <W	**1.3**
AA Churchill Ave.	front	3800	14000	8300	3100	360	25	30	24	17	23	9.0 <T	9.0	14	4.6	11	0.5 <W	0.5 <W	0.2 <W
AA Churchill Ave.	front	3300	12000	7700	2800	320	23	28	22	14	21	16	8.0	13	4.7	11	0.5 <W	0.5 <W	0.7 <T
AA Churchill Ave.	back	2700	11000	7100	2500	270	21	28	22	13	19	9.0 <T	7.0	12	4.7	8.4	0.5 <W	0.5 <W	0.3 <T
AA Churchill Ave.	back	3000	12000	7900	2800	360	24	30	24	15	21	10	8.0	13	4.0	15	0.5 <W	0.5 <W	0.2 <W
AB Churchill Ave.	front	3900	20000	11000	3200	990	67	120	35	21	26	47	19	15	6.0	**20**	0.5 <W	0.5 <W	0.9 <T
AB Churchill Ave.	front	4200	20000	11000	3200	1100	67	110	38	21	26	38	17	14	6.1	**22**	0.5 <W	0.5 <W	0.7 <T
AB Churchill Ave.	back	3500	18000	10000	3400	500	25	78	32	17	25	23	14	16	6.3	17	0.5 <W	0.5 <W	0.6 <T
AB Churchill Ave.	back	3300	16000	10000	3400	610	35	76	30	16	26	15	13	17	6.6	**23**	0.5 <W	0.5 <W	0.4 <T
AC Magpie Rd.	front	4200	14000	8100	3300	440	31	35	25	20	27	16	17	15	5.0	**27**	0.5 <W	0.5 <W	0.4 <T
AC Magpie Rd.	front	4600	16000	8300	3400	530	33	34	26	22	26	12	18	15	5.5	15	0.5 <W	0.5 <W	0.4 <T
AC Magpie Rd.	back	3500	21000	12000	3400	590	45	46	35	19	25	17	18	17	6.0	**25**	0.5 <W	0.5 <W	0.5 <T
AC Magpie Rd.	back	3300	22000	11000	3400	650	48	44	37	20	25	24	16	16	5.6	**25**	0.5 <W	0.5 <W	0.6 <T
AD Third Ave.	front	5300	23000	11000	4600	760	43	73	33	22	32	47	20	19	6.8	**18**	0.5 <W	0.5 <W	0.5 <T
AD Third Ave.	front	4700	23000	9700	4600	760	38	68	31	21	31	40	20	19	7.2	**18**	0.5 <W	0.6 <T	0.7 <T
AD Third Ave.	back	4100	21000	11000	4800	620	35	51	37	23	36	20	31	23	7.9	**18**	0.5 <W	0.5 <W	0.4 <T
AD Third Ave.	back	4300	22000	11000	5000	680	40	65	35	19	32	25	20	23	8.1	**19**	0.5 <W	0.5 <W	0.6 <T
AE George St.	front	3700	14000	9100	2600	400	46	40	26	20	24	22	14	13	4.6	**21**	0.5 <W	0.6 <T	0.6 <T
AE George St.	front	3300	14000	9800	2500	430	37	40	25	17	24	17	13	13	4.7	16	0.5 <W	0.5 <W	0.4 <T
AE George St.	back	2500	14000	8200	2600	380	24	39	25	15	23	20	10	13	3.9	**21**	0.5 <W	0.5 <W	0.5 <T
AE George St.	back	2900	14000	9000	3000	370	24	38	27	16	24	21	11	14	4.2	**19**	0.5 <W	0.5 <W	0.5 <T
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available

Table 3: Soil Element Concentrations (ug/g) on Residential Yards, Wawa Townsite Properties West of Third Ave. & Mission Rd.

Address	Yard	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
AF Ross St.	side	3200	16000	8900	2800	420	27	37	29	15	22	17	12	12	4.8	15	0.5 <W	0.5 <W	0.6 <T
AF Ross St.	side	2600	14000	7800	2100	380	28	31	26	13	18	17	8.0	9.0	3.7	14	0.5 <W	0.5 <W	0.4 <T
AF Ross St.	front	3700	15000	7500	3000	430	26	42	26	14	27	21	11	12	4.2	**18**	0.5 <W	0.5 <W	0.6 <T
AF Ross St.	front	3900	15000	7600	3000	420	29	39	26	15	26	18	12	13	4.4	13	0.5 <W	0.5 <W	0.2 <W
AF Ross St.	back	4800	16000	9200	3200	510	36	59	28	14	21	22	12	13	4.7	16	0.5 <W	0.5 <W	0.4 <T
AF Ross St.	back	4200	15000	8600	2900	450	33	54	26	15	20	21	11	12	5.2	**20**	0.5 <W	0.5 <W	0.9 <T
AG Birch St.	front	2900	15000	7900	2100	460	24	25	23	13	17	12	7.0	9.4	3.5	**26**	0.5 <W	0.5 <W	0.2 <W
AG Birch St.	front	2700	15000	8300	1900	420	23	23 <T	24	12	17	12	6.0	9	3.1	**28**	0.5 <W	0.5 <W	0.3 <T
AG Birch St.	back	3800	14000	8000	2200	500	41	51	23	21	19	19	13	12	3.5	17	0.5 <W	0.5 <W	0.3 <T
AG Birch St.	back	2600	14000	7700	2100	400	25	35	23	14	19	15	8.0	11	3.9	**19**	0.5 <W	0.5 <W	0.5 <T
AH Churchill Ave.	front	3200	15000	9400	2400	420	20	63	26	13	24	21	11	11	3.7	**25**	0.5 <W	0.5 <W	0.2 <W
AH Churchill Ave.	front	3000	14000	9100	2300	380	19	43	24	11	24	24	10	10	3.5	**22**	0.5 <W	0.5 <W	0.2 <W
AH Churchill Ave.	back	3300	20000	10000	3200	680	38	42	40	15	31	16	13	16	5.8	**34**	0.5 <W	0.5 <W	0.4 <T
AH Churchill Ave.	back	3500	19000	9600	3100	660	39	51	38	14	29	20	12	14	5.3	**28**	0.5 <W	0.6 <T	0.5 <T
Al Poplar St.	front	3300	15000	7800	3100	380	22	23 <T	29	18	27	10	12	13	4.9	11	0.5 <W	1.0 <T	0.4 <T
Al Poplar St.	front	3800	17000	8800	3200	420	25	29	33	21	28	9.0 <T	14	15	5.6	13	0.5 <W	0.6 <T	0.2 <W
Al Poplar St.	back	2700	19000	7600	3100	520	26	36	35	17	27	10	15	16	5.4	17	0.5 <W	0.5 <W	0.2 <W
Al Poplar St.	back	2700	17000	6800	2900	460	25	36	30	17	22	7.0 <T	13	13	5.3	14	0.5 <W	0.7 <T	0.2 <W
AJ Tamarack Ave.	front	3400	12000	6500	3000	320	20	31	22	14	25	8.0 <T	13	20	4.9	4.6	0.5 <W	0.5 <W	0.2 <W
AJ Tamarack Ave.	front	3600	13000	6600	3000	340	22	35	22	16	27	8.0 <T	14	21	4.8	5.0	0.5 <W	0.5 <W	0.4 <T
AJ Tamarack Ave.	back	4000	19000	22000	3700	450	130	85	39	24	49	4.0 <T	68	61	8.7	4.1	0.8 <T	0.5 <W	0.4 <T
AJ Tamarack Ave.	back	3400	16000	18000	3300	380	100	67	34	20	42	4.0 <T	55	50	7.1	4.9	0.6 <T	0.5 <W	0.4 <T
AK Tamarack Ave.	front	3600	13000	6900	2900	370	23	31	24	17	21	7.0 <T	16	21	4.9	4.3	0.5 <W	0.5 <W	0.4 <T
AK Tamarack Ave.	front	3800	14000	6900	3000	440	25	30	23	18	22	6.0 <T	15	20	5.3	7.4	0.5 <W	0.5 <W	0.2 <W
AK Tamarack Ave.	back	4100	18000	16000	3600	460	93	75	33	22	41	7.0 <T	56	**49**	7.6	4.5	0.6 <T	0.5 <W	0.2 <W
AK Tamarack Ave.	back	3700	15000	13000	3200	380	71	66	29	20	34	5.0 <T	41	39	6.7	3.6	0.5 <W	0.5 <W	0.2 <W
AL Superior Ave.	front	2400	12000	8000	3000	280	24	60	27	15	23	6.0 <T	12	15	5.7	11	0.5 <W	0.5 <W	0.2 <W
AL Superior Ave.	front	3300	12000	8100	3200	320	35	29	26	19	24	4.0 <T	12	16	6.0	6.2	0.5 <W	0.5 <W	0.2 <W
AM George St.	front	5000	12000	7000	3000	350	43	66	22	22	27	23	20	16	5.2	13	0.5 <W	0.5 <W	0.4 <T
AM George St.	front	5100	12000	6600	2900	360	43	44	22	21	25	33	20	15	4.9	14	0.5 <W	0.5 <W	0.2 <W
AM George St.	back	2900	13000	7500	2300	340	29	44	26	13	27	22	10	11	4.7	17	0.5 <W	0.5 <W	0.6 <T
AM George St.	back	3800	14000	7700	2800	360	30	85	27	15	27	25	11	11	4.2	16	0.5 <W	0.5 <W	**1.2**
MOE Background Guideline		58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0
MOE Effects Guideline		NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 4: Correlation Coefficients (r) Between Pairs of Soil Chemical Elements

	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd
Ca	1																	
Fe	0.4559	1																
Al	0.3475	0.3482	1															
Mg	0.6559	0.7751	0.4512	1														
Mn	0.5336	0.9270	0.1660	0.6689	1													
Ba	0.5748	0.3014	0.8131	0.3234	0.2798	1												
Zn	0.5022	0.6279	0.4203	0.5027	0.5995	0.4977	1											
V	0.3784	0.5176	0.7753	0.6110	0.3301	0.5666	0.5093	1										
Sr	0.7908	0.2413	0.3202	0.3623	0.3742	0.6683	0.3592	0.3300	1									
Cr	0.4922	0.4891	0.8814	0.6948	0.3025	0.6913	0.5306	0.8046	0.3367	1								
Pb	0.2475	0.4042	-0.0186	0.2379	0.3861	0.0666	0.6819	0.1870	0.1231	0.1190	1							
Cu	0.4756	0.4442	0.9027	0.5830	0.2774	0.7839	0.4399	0.6403	0.3370	0.8863	0.0627	1						
Ni	0.3167	0.3509	0.9017	0.4506	0.1758	0.7842	0.3749	0.6068	0.2828	0.8415	-0.0758	0.9054	1					
Co	0.5319	0.5723	0.7587	0.8162	0.4073	0.5631	0.5459	0.8245	0.3887	0.8876	0.1776	0.7681	0.7100	1				
As	0.2360	0.6355	-0.0167	0.3935	0.6577	-0.0005	0.3899	0.1496	0.0668	0.1333	0.3085	0.0633	0.0111	0.1635	1			
Be	0.1481	0.1389	0.8222	0.1476	-0.0089	0.7591	0.2207	0.4499	0.1894	0.6448	-0.1680	0.7577	0.8549	0.4534	-0.1024	1		
Mo	0.0767	0.1399	0.2404	0.2773	0.0314	0.0026	-0.0461	0.3410	0.0107	0.3020	-0.0446	0.2221	0.0867	0.3995	-0.0561	-0.0080	1	
Cd	0.4524	0.5189	0.2736	0.3901	0.5237	0.3741	0.6173	0.3707	0.3713	0.3230	0.5726	0.2923	0.1637	0.3843	0.1963	0.1108	0.0774	1

Table 5: Element Concentrations (ug/g) - Soil Used in Bioassay (mean of 3 or 4 analytical replicates)

	Ca	Fe	Al	Mg	Mn	Ba	Zn	V	Sr	Cr	Pb	Cu	Ni	Co	As	Be	Mo	Cd	Na	Cl
Site 1	3900	22250	9150	4750	645	32	69	33	22	34	32	27	22	8.2	14	0.5	0.7	0.5	118	13
Site 2	6675	**110000**	7450	9400	**5475**	49	62	36	18	22	33	14	23	6.2	**348**	0.5	0.5	1.3	70	7.5
Site 3	3700	**37000**	20750	4150	1200	55	79	43	19	36	40	20	23	7.6	**108**	0.5	0.6	1.0	118	19
Site 4	8100	**143333**	7867	12333	**7967**	28	120	31	16	31	60	49	27	8.9	**390**	0.5	0.5	2.1	100	4.8
Site 5	3200	15333	9667	2467	393	38	37	28	16	24	11	13	14	5.1	15	0.5	0.5	0.6	77	2.7
Site 6	22000	**263333**	6500	**21000**	**15333**	21	81	23	37	26	3.3	30	40	19	**497**	0.5	0.5	3.3	67	2.1
Site 7	5267	17000	6733	4200	483	24	47	28	17	34	10	17	18	7.3	14	0.5	0.5	0.6	87	4.5
Site 8	6600	**163333**	6700	14333	**9400**	60	**203**	29	17	43	103	40	32	11	**533**	0.5	0.5	2.5	117	8.8
Site 9	3867	40333	11333	3767	**1900**	27	56	21	12	20	19	7.0	14	4.3	**143**	0.5	0.5	0.8	60	4.5
Site 10	3200	27333	9467	3533	1133	39	51	28	17	26	36	22	21	6.7	**60**	0.5	0.5	0.5	73	6.1
Table F Guideline	58000	33000	27000	16000	1300	210	160	91	78	71	120	85	43	21	17	1.2	2.5	1.0	910	220
Table A Guideline	NG	NG	NG	NG	NG	750	600	200	NG	750	200	225	200	40	20	1.2	40	12	NG	NG

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available.

Table 6: Summary of Arsenic Bean Growth Bioassay Results

Sample Site	Soil Arsenic in µg/g	Mean Shoot Fresh Weight in g (STD)	Mean Shoot Length in cm (STD)	Mean Root Length in cm (STD)
Control	<17	1.71 (2.63)	11.54 (3.56)	17.08 (2.09)
1	14	2.25 (3.48)	14.27 (1.44)	16.60 (4.24)
7	14	2.67 (4.38)	13.03 (1.99)	19.52 (3.97)
5	15	2.48 (3.82)	12.60 (2.25)	17.82 (3.06)
10	60	1.99 (2.88)	12.09 (2.41)	18.76 (3.20)
3	108	2.95 (4.61)	13.51 (1.17)	17.03 (2.82)
9	143	2.26 (3.41)	11.73 (2.16)	18.78 (1.99)
2	348	2.22 (3.63)	13.30 (1.05)	23.63 (5.31)
4	390	2.46 (3.63)	13.87 (2.15)	20.03 (3.73)
6	497	2.42 (3.14)	12.47 (2.32)	13.75 (2.72)
8	533	1.77 (2.56)	12.20 (1.03)	18.75 (3.66)
Mean of 15 plants per treatment STD - Standard Deviation				

Figure 1: Location of Residential Properties Sampled and Bioassay Soil Collected

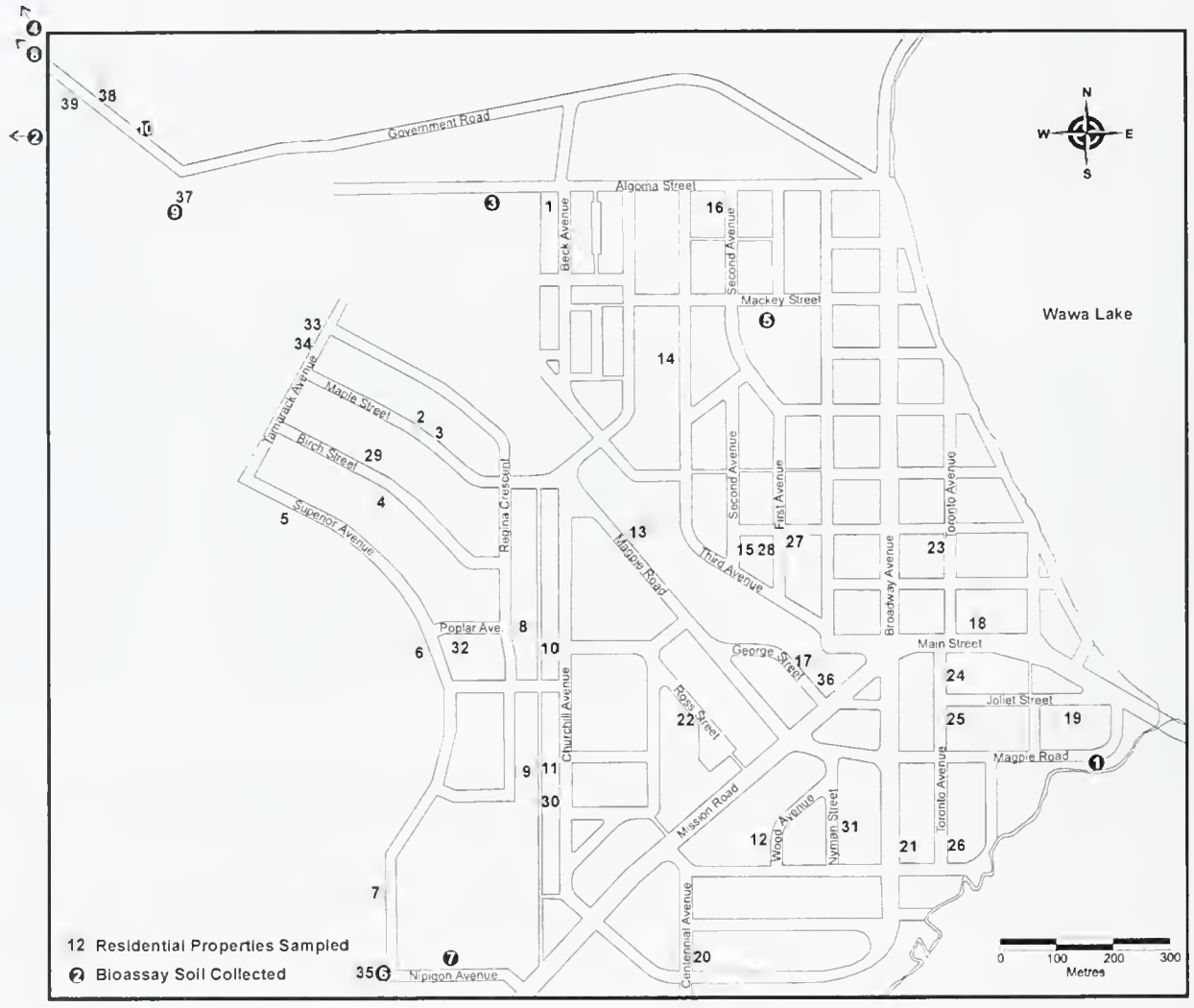


Figure 2:

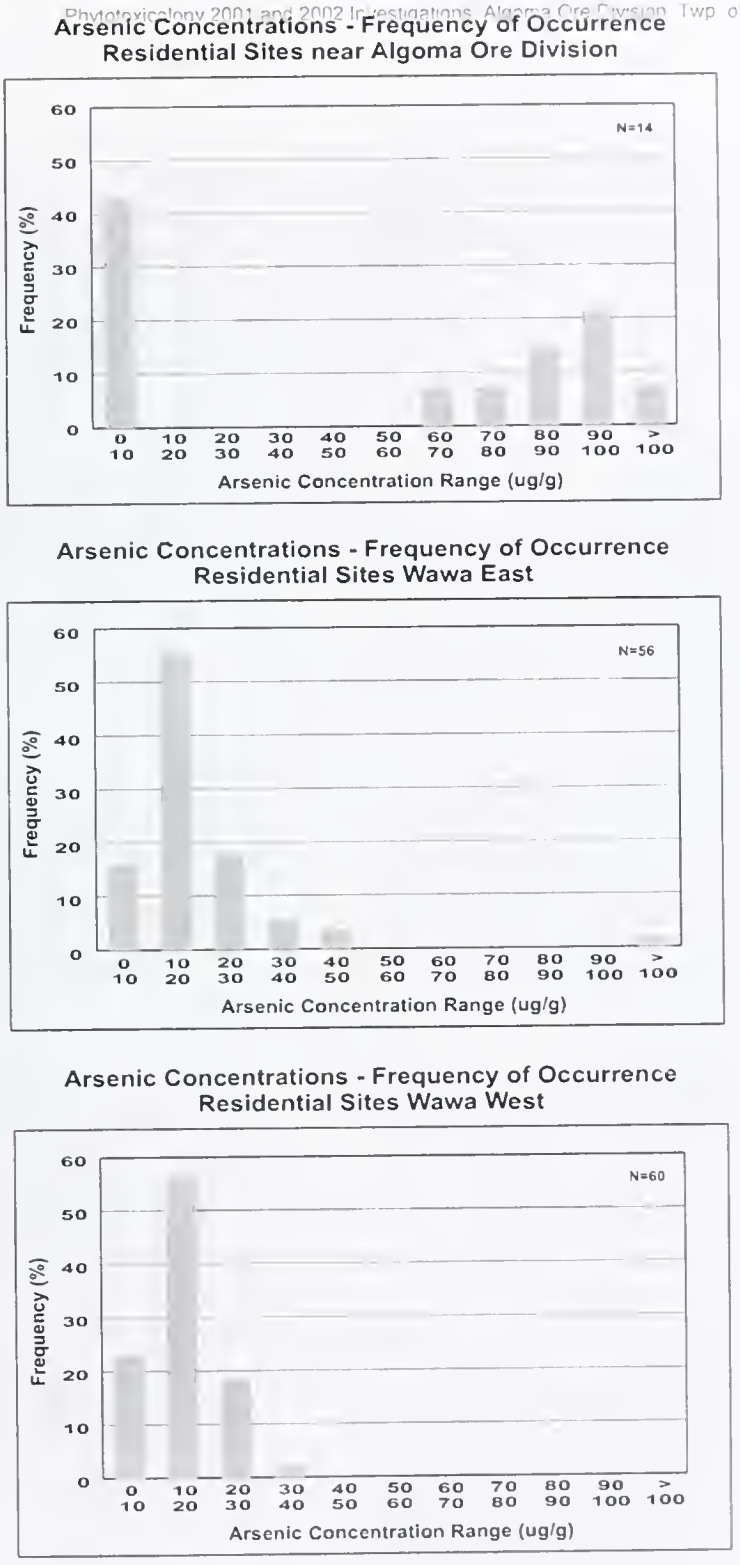
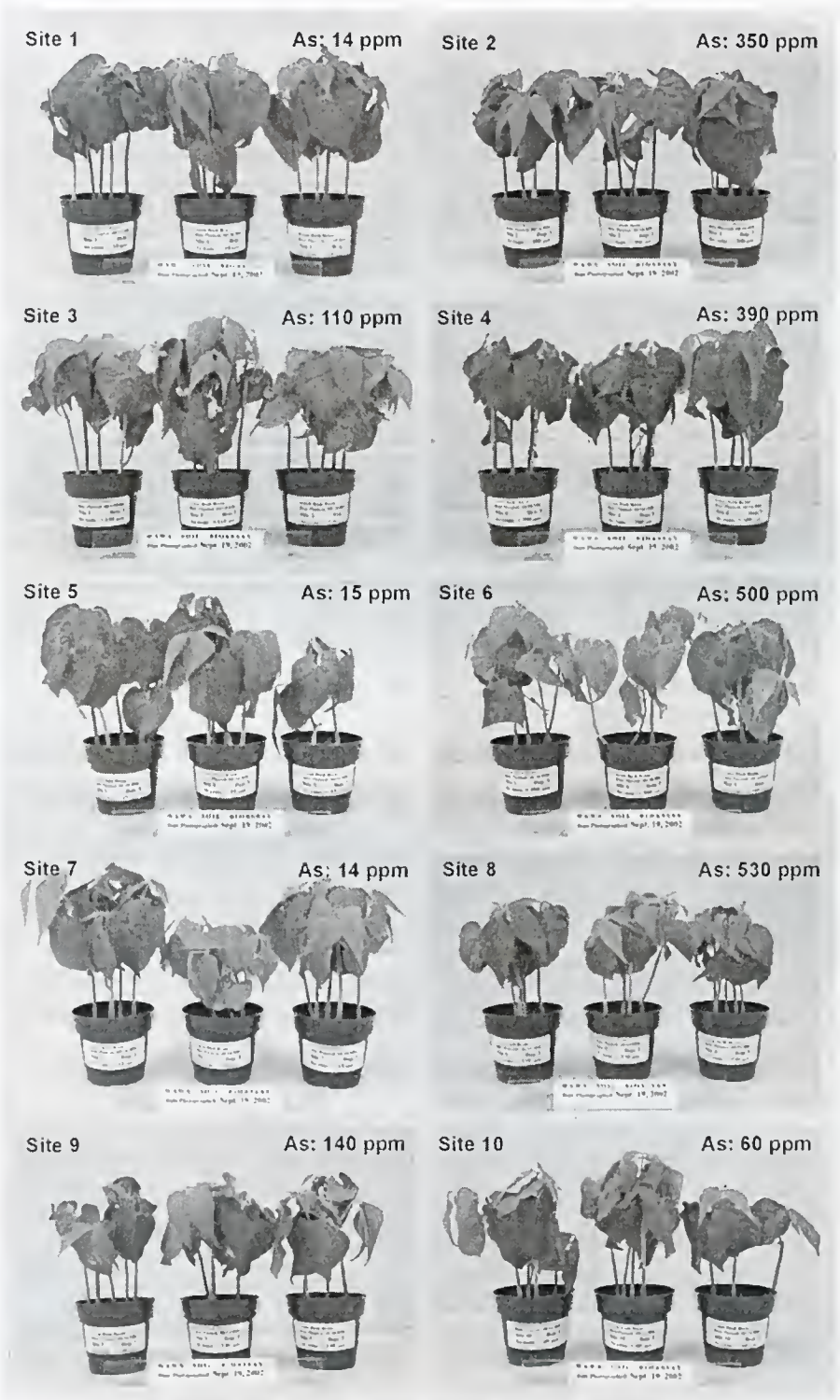

Arsenic Concentrations - Frequency of Occurrence
Residential Sites near Algoma Ore Division
N=14
Frequency (%)
0
10
20
30
40
50
60
0 10
10 20
20 30
30 40
40 50
50 60
60 70
70 80
80 90
90 100
> 100
Arsenic Concentration Range (ug/g)
Arsenic Concentrations - Frequency of Occurrence
Residential Sites Wawa East
N=56
Frequency (%)
Arsenic Concentration Range (ug/g)
Arsenic Concentrations - Frequency of Occurrence
Residential Sites Wawa West
N=60
Frequency (%)
Arsenic Concentration Range (ug/g)

Figure 3: Bush Bean Plants Grown for 35 Days in 10 Soils from the Wawa Area



Appendix 1

Derivation/Significance of the Ontario Ministry of the Environment (MOE) Soil Guidelines in "*Guideline for Use at Contaminated Sites in Ontario*"

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* ***may not*** ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded ***and*** where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually

contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.

Appendix 2
Derivation and Significance of the MOE "Ontario Typical Range" Soil Guidelines

The MOE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (the OTR_{98} is the actual guideline number) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the anticipated average, and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. As a result, it must be stressed that values falling within a specific OTR98 should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans. Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or

extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow, MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.

Ministry of Environment
Laboratory Services Branch
Current/Active LSB Analytical Methods - Drinking Water

Method	Description
E3015A	THE DETERMINATION OF FREE AND TOTAL CYANIDE IN ENVIRONMENTAL SAMPLES BY COLOURIMETRY
E3016A	THE DETERMINATION OF CHLORIDE IN DRINKING WATER, SURFACE WATER, SEWAGE AND INDUSTRIAL WASTE BY COLOURIMETRY
E3051A	THE DETERMINATION OF TRACE METALS IN POTABLE WATERS BY INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (ICP-MS)
E3056A	THE DETERMINATION OF HEXAVALENT CHROMIUM IN WATER, LANDFILL LEACHATES AND EFFLUENTS BY COLOURIMETRY
E3060B	THE DETERMINATION OF MERCURY IN WATER BY COLD VAPOUR-FLAMELESS ATOMIC ABSORPTION SPECTROPHOTOMETRY (CV-FAAS)
E3100A	THE DETERMINATION OF TOTAL SULPHIDE IN WATER, SEWAGE AND INDUSTRIAL WASTES BY COLOURIMETRY
E3115A	THE ENUMERATION OF "SULPHATE REDUCING" BACTERIA IN WATER BY THE INDICATED NUMBER METHOD
E3119A	THE DETERMINATION OF CHLOROPHENOLS (CPS) AND PHENOXYACID HERBICIDES (PAS) IN WATER BY SOLID PHASE EXTRACTION (SPE) AND IN VEGETATION BY SOLID/LIQUID EXTRACTION (SONIFICATION) USING GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)
E3132A	THE DETERMINATION OF VOLATILE ORGANOHALIDES AND HYDROCARBONS IN WATER, LEACHATES AND EFFLUENTS BY HEADSPACE CAPILLARY GAS CHROMATOGRAPHY (GC) MASS SPECTROMETRY AND/OR PURGE AND TRAP GAS CHROMATOGRAPHY (GC) MASS SPECTROMETRY
E3144B	THE DETERMINATION OF VOLATILE ORGANIC COMPOUNDS IN RAW AND TREATED DRINKING WATER BY PURGE AND TRAP CAPILLARY GAS CHROMATOGRAPHY- FLAME IONIZATION/MASS SELECTIVE (PT/GC-FID/MSD) DETECTION
E3170A	THE DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD) IN DOMESTIC AND SURFACE WATERS BY COLOURIMETRY
E3172A	THE DETERMINATION OF FLUORIDE AND SULPHATE IN WATER, LEACHATES AND EFFLUENTS BY AUTOMATED ION CHROMATOGRAPHY (IC)
E3179A	THE DETERMINATION OF PHENOLIC COMPOUNDS IN WATER, INDUSTRIAL WASTES, LANDFILL LEACHATES AND SEWAGE BY COLOURIMETRY
E3186A	THE CHARACTERIZATION OF EXTRACTABLE ORGANICS IN WATER, WASTE AND SOIL BY GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)
E3188B	THE DETERMINATION OF SOLIDS IN LIQUID MATRICES BY GRAVIMETRY
E3189A	THE CHARACTERIZATION OF VOLATILE ORGANICS IN WATER AND EFFLUENT BY PURGE-AND-TRAP GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)
E3196A	LIMS CALCULATIONS-ION BALANCE

Method	Description
E3217A	THE DETERMINATION OF CATIONS IN WATER, SEWAGE, HEALTH SAMPLES, INDUSTRIAL WASTE AND LANDFILL LEACHATES BY ATOMIC ABSORPTION SPECTROPHOTOMETRY (AAS)
E3218A	THE DETERMINATION OF CONDUCTIVITY, pH AND ALKALINITY IN WATER AND EFFLUENTS BY POTENTIOMETRY
E3219A	THE DETERMINATION OF TRUE COLOUR IN WATER, EFFLUENTS AND INDUSTRIAL WASTES BY COLOURIMETRY
E3226A	THE DETECTION OF COLIFORM BACTERIA INCLUDING ESCHERICHIA COLI IN DRINKING WATER BY THE PRESENCE-ABSENCE PROCEDURE
E3247B	THE DETERMINATION OF TOTAL ORGANIC CARBON IN AQUEOUS SAMPLES BY COMBUSTION AND INFRARED SPECTROMETRY
E3274A	LIMS CALCULATIONS-LANGELIERS INDEX
E3291A	THE DETERMINATION OF N-NITROSODIMETHYLAMINE (NDMA) IN WATER BY GAS CHROMATOGRAPHY-HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS)
E3310A	THE DETERMINATION OF TASTE AND ODOUR COMPOUNDS IN WATER BY GAS CHROMATOGRAPHY-HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS)
E3311A	THE DETERMINATION OF TURBIDITY IN WATER BY NEPHELOMETRY UNDER ROBOTIC CONTROL
E3364A	THE DETERMINATION OF AMMONIA NITROGEN, NITRITE NITROGEN, NITRITE PLUS NITRATE NITROGEN AND REACTIVE ORTHO-PHOSPHATE IN SURFACE WATER, DRINKING WATER AND PRECIPITATION BY COLOURIMETRY
E3367A	THE DETERMINATION OF TOTAL KJELDAHL NITROGEN AND TOTAL PHOSPHOROUS IN WATER, PRECIPITATION AND SOIL EXTRACTS BY COLOURIMETRY
E3370A	THE DETERMINATION OF MOLYBDATE REACTIVE SILICATES AND DISSOLVED CARBON IN WATER, INDUSTRIAL WASTE, SOIL EXTRACTS AND PRECIPITATION BY COLOURIMETRY
E3371A	A MEMBRANE FILTRATION METHOD FOR THE DETECTION AND ENUMERATION OF TOTAL COLIFORM, ESCHERICHIA COLI, PSEUDOMONAS AERUGINOSA AND FECAL STREPTOCOCCI
E3388A	THE DETERMINATION OF N-NITROSAMINES IN WATER BY GAS CHROMATOGRAPHY - HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS)
E3399A	THE DETERMINATION OF POLYCYCLIC HYDROCARBONS (PAH) IN AQUEOUS MATRICES BY LIQUID-LIQUID MICRO-EXTRACTION (LLME) AND GAS CHROMATOGRAPHY - MASS SPECTROMETRY (GC-MS)
E3400A	THE DETERMINATION OF ORGANOCHLORINE PESTICIDES, CHLOROBENZENES (CBS), AROCLORS AND TOXAPHENES IN WATER, EFFLUENT AND WASTEWATER BY HEXANE MICROEXTRACTION AND GAS CHROMATOGRAPHY - MASS SPECTROMETRY (GC-MS)
E3406A	THE DETERMINATION OF NITRILOTRIACETIC ACID (NTA) IN AQUEOUS SAMPLES BY AUTOMATED ION CHROMATOGRAPHY (IC)

Method	Description
E3407A	MEMBRANE FILTRATION METHOD USING DC AGAR FOR THE SIMULTANEOUS DETECTION AND ENUMERATION OF TOTAL COLIFORMS AND ESCHERICHIA COLI
E3408A	THE SPREAD PLATE METHOD FOR THE ENUMERATION OF AEROBIC HETEROTROPHIC BACTERIA IN DRINKING WATER
E3415	THE DETERMINATION OF GLYPHOSATE AND AMINOMETHYLPHOSPHONIC ACID IN WATER AND VEGETATION BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY -ELECTROSPRAY IONIZATION- MASS SPECTROMETRY (HPLC-EI-MS)
E3417	THE DETERMINATION OF DIQUAT AND PARAQUAT IN WATER, SOIL AND VEGETATION ENVIRONMENTAL MATRICES BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) PHOTDIODE ARRAY AND/OR ELECTRO-SPRAY MASS SPECTROMETRY (MS)
E3418	THE DETERMINATION OF POLYCHLORINATED DIBENZO-P-DIOXINS, POLYCHOLRDIBENZOFURANS AND DIOXIN-LIKE POLYCHLORINATED BIPHENYLS IN ENVIRONMENTAL SAMPLES BY GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)
E3430	THE DETERMINATION OF BROMINATED DIPHENYL ETHERS IN ENVIRONMENTAL MATRICES BY GAS CHROMATOGRAPHY/HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS)
E3434	THE DETERMINATION OF BROMIDE IN SOURCE WATER BY ION CHROMATOGRAPY/ELECTROCHEMICAL DETECTION AND TRACE LEVELS OF BROMATE IN OZONATED DRINKING WATER WITH THE ADDITION OF POSTCOLUMN REAGENT AND A UV/VISIBLE DETECTOR
E3435	THE DETERMINATION OF POLYCYCLIC AROMATIC HYDROCARBONS AND TRIAZINE PESTICIDES IN WATER MATRICES BY GAS CHROMATOGRAPHY-TIME OF FLIGHT-MASS SPECTROMETRY
E3436	THE DETERMINATION OF PHENYL UREAS IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS
E3437	THE DETERMINATION OF ORGANOPHOSPHORUS PESTICIDES IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS
E3438	THE DETERMINATION OF CARBAMATES IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS
E3449	THE DETERMINATION OF MOSQUITO LARVACIDE AND ADULTICIDE AND THE SCREENING OF DECOMPOSITION BY-PRODUCTS OF METHOPRENE IN ENVIROMENTAL MATRICES USING MICRO-EXTRACTION AND GAS CHROMATOGRAPHY-TIME OF FLIGHT-MASS SPECTROMETRY
E3450	THE DETERMINATION OF MICROCYSTINS AND NODULARIN IN WATER BY LIQUID CHROMATOGRAPHY-(ELECTROSPRAY IONIZATION) TANDEM MASS SPECTROMETRY [LC-(ESI)MS/MS]
E3451	THE DETECTION AND ENUMERATION OF BACILLUS THURINGIENSIS VAR. ISRAELENSIS (BTI) IN DRINKING WATER BY MEMBRANE FILTRATION AND THE COLONY PCR METHOD
E3454	THE DETERMINATION OF PHARMACEUTICALS IN ENVIRONMENTAL MATRICES BY LIQUID CHROMATOGRAPHY/MASS SPECTROMETRY/MASS SPECTROMETRY